ESTIMATION FOR DYNAMIC MEASUREMENT OF SCAPULA KINEMATICS USING ELECTROMAGNETIC TRAKING DEVICE

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INTRODUCTION

Scapula motion is an important element of upper limb movement, and therefore several investigators have developed methods for measuring three-dimensional and dynamic scapula kinematics. Recently, *acromial method* [1] using electromagnetic sensor was investigated. Although this method is three-dimensional, dynamic, noninvasive and practical, sliding of scapula under skin prevents accurate measurement [2]. The purpose of this study was to examine the error pattern in *acromial method* during humerus elevation.

METHODS

Six adult subjects with functionally normal shoulder girdles participated. Kinematic data were collected with electromagnetic tracking device (Plhemus, LIVERTY). Sensors were attached to the skin on acromion, sternum and a three-pin device according to Johnson [3], which was scapula locator by palpating landmark. Scapula orientations from thorax coordinate system were recorded during humerus elevation, and expressed in Euler angle, which are comprised of three angles. These angles represented external rotation (ER), upward rotation (UR) and tilting (TI). Humerus elevations were performed in 76 positions: 19 humerus elevations per 10˚ and 4 elevation planes per 30˚. The error of bone and skin based measurement was computed for each angle. Each rotation error was separately compared with a 19 (humerus elevation: HE) × 4 (elevation plane: EP) repeated measures ANOVA.

After examinating the error pattern, estimation was tested. Estimation models were developed for each subject. The models were made by multiple linear regression: predictor was skin orientation and estimator was Scapula orientation. For practical application, samples were required to be small and easy to obtain. Therefore, 25 positions, 6 humerus elevations × 4 elevation planes in steps of 30˚ + 1 rest position, were selected. As the number of samples decreased from 25 to 2 samples, root mean squared error on average in all subjects (ARMSE) was observed and evaluated.

Table 1: The error of scapula and skin orientation.

Rotation	Factor	DOF	f-value	p-value
ER	HE	18	19.827	.000 **
	EP	3	0.417	.743
	HE×EP	54	2.280	.000 **
UR	HE	18	14.828	.000 **
	EP	3	12.315	.000 **
	HE×EP	54	2.370	.000 **
TI	HE	18	9.996	.000 **
	EP	3	5.990	.007 **
	HE×EP	54	1.952	.000 **

** p<.01

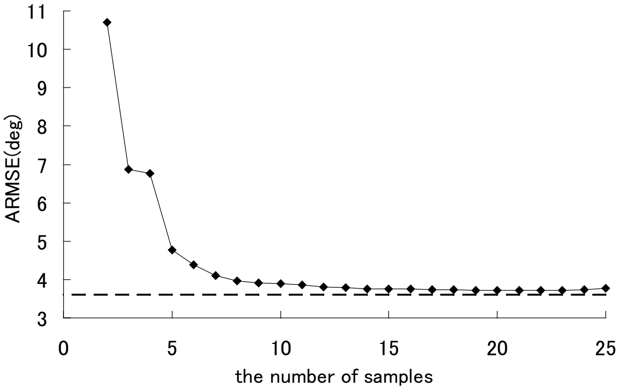

Figure 1: The change of ARMSE for the number of samples. Broken line expressed ARMSE by regression using all samples.

RESULTS AND DISCUSSION

All errors had HE × EP interaction (Table 1), therefore HE differently affected to error patterns in each EP. These complex errors were caused by slack of skin. During humerus elevation, the distance between scapula and humerus was partly contracted then the skin on acromion was slacked. Though the amount of the errors was individually different, the error patterns across all subjects were identified.

Systematic error pattern allowed estimation of regression. ARMSE was decreased from 20.3˚ (no regression) to 3.6˚ (using all samples). Focusing the number of samples (Figure 1), ARMSE obviously increased under 10 samples, while it did not clearly changed over 15 samples. To consider estimation accuracy and time cost for sampling, using about 10 to 15 samples was practical. Then, the number of samples decreasing, remained samples were based between low elevation in frontal plane and high elevation in sagittal plane. It was suggested that employing sampling position was based on this positions.

CONCLUSIONS

The error patterns were examined for humerus elevation and elevation plane. Employing linear regression, dynamic measurement of scapula kinematics from skin is possible. For practical way, the number of samples and sampling humerus positions were suggested.

REFERENCES

1. McQuade KJ, et al. *JOSPT*, 27 (2), 125-133, 1998.
2. Karduna AR, et al. *J Biomech Eng,* 123**,** 184-190, 2001.
3. Johnson GR, et al. *Clinic Biomech*, 8 (5), 269-273, 1993